



AGRICULTURAL EXPERIMENT STATION
Department of Biological and Agricultural Engineering
149 E.B. Doran Bldg. – LSU
Baton Rouge, LA 70803-4505
(225) 578-3153
Fax: (225) 578-3492
www.lsuagcenter.com

Calibration of Sprayers

- Calibration is the process of adjusting sprayer components in order to deliver the desired volume (rate) per area when applying chemical products. Why do we calibrate sprayers?
 - ✓ To ensure that the correct volume is being delivered per unit of area.
 - ✓ To ensure that mixture of water and active ingredient is being done correctly.
- One of the most important objectives during spraying is the delivery of the correct volume per area (gallons per acre). The efficiency of the chemical is intimately dependent on the application of an accurate rate.
- There are four very important checks to be done in the sprayer to assure proper calibration, they are:
 - ✓ **Speed.** Speed determines operation productivity (acre/hr or acre/day). For sprayers not equipped with electronic flow control, maintaining proper speed is critical to achieve the correct rate distribution (gallons per acre or GPA). Misapplication is directly related to errors in speed. When the sprayer is equipped with an electronic flow control, small variations in speed are compensated by the controller.
 - ✓ **Effective Swath Width.** The swath width determines the area treated with each pass of the sprayer. In *broadcast* operations, effective swath width is generally equal to nozzle spacing. In **banding** operations, swath width is equal to the band width. In *direct applications*, where nozzles are directed to the plants or to the rows, the effective swath width is $\frac{rs}{n}$, where rs is the row spacing and n is the number of nozzles per row.
 - ✓ **Nozzle Flow.** Agricultural nozzles produce a determined flow per unit of time. This flow is pressure dependent. It is important to know for a particular type of nozzle and operating pressure, what is the flow per unit time.
 - ✓ **Operating Pressure.** Also very important in the calibration process. Pressure affects the volume delivered by the nozzles. Increasing pressure increases nozzle flow, but the relationship is not linear.
- How to calibrate a sprayer? Follow these simple steps to assure proper calibration.

1. Speed Check

- Make sure you know at what speed you're spraying. With the advent of automatic spray controllers, many people assume that speed is not an issue in calibration anymore, and that the computer will compensate for it. That's not always the case. During calibration it is very important to know the average speed of the sprayer. Follow this simple procedure to find out.
 - ✓ Measure a distance between 100 to 200 feet in a location that resembles the ground where you often spray.

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- ✓ Using the same tractor gear arrangements that are used during spraying, record the time in seconds spent to cover the distance marked. For better accuracy, check the speed with the sprayer carrying a half load.
- ✓ Repeat this process 3 or 4 times.
- ✓ Calculate the speed using the following equation: $S = \frac{L}{T} \times 0.6818$. Where S represents the calculated speed (mph), L stands for the length (feet) and T for time (seconds). 0.6818 is a conversion factor to transform the units from feet per second to miles per hour.

Let's work out an example:

- Length marked: 150 feet.
- Time spent:
 - 1st Time: 11.5 seconds
 - 2nd Time: 11.1 seconds
 - 3rd Time: 11.3 seconds
 - 4th Time: 11.2 seconds
 - Average Time Spent: $\frac{11.5+11.1+11.3+11.2}{4} = 11.3 \text{ s}$
- The speed is then calculated as

$$S = \frac{150 \text{ feet}}{11.3 \text{ seconds}} \times 0.6818 = 9 \text{ mph}$$

2. Effective Swath Width

- Effective swath width as explained before is the area covered by the sprayer during operation. In broadcast spraying, the swath width is equal to nozzle spacing. In banding spraying, swath width is equal to the treated band. In direct spraying, swath width is equal to the row spacing divided by the number of nozzles per row.

Let's work out a few examples:

- ✓ In a direct application, sugar cane is planted in 72-in rows, and 2 nozzles are used per row to direct spray solution to those plants, what is the effective swath width?

Answer: As we stated before, effective swath width will be the row spacing divided by the number of nozzles per row. In this case, $\frac{72 \text{ in}}{2}$ will yield an effective swath width of 36 inches.

- ✓ In herbicide application in sugar cane, 3 nozzles are directed to the plants, the row spacing is 72 inches, but the spray is directed only to 36 inches. What is the effective swath width?

Answer: This is a case of direct and band application mixed together. Since there are 3 nozzles directed to the plants but only the banded portion is being sprayed, the effective swath width will be $\frac{36}{3}$ or 12 inches.



3. Nozzle Flow

- ✓ It is very important to check nozzle flow to be sure that they are
 - free of foreign objects and obstructions,
 - within the operating flow range defined by the manufacturer.

Before collecting flow information from the nozzles, clean all strainers and eliminate all foreign materials from the nozzles. Be sure that you have the same type of nozzle in the entire boom. One of the most common mistakes in a calibration procedure is to find different nozzles, or sometimes nozzles with different orifice sizes alongside the boom. Check nozzles for uniformity of flow. Usually nozzles are encoded with numbers that inform their angle of spray and flow at 40 PSI of pressure. Therefore an 11004 nozzle produces a spray angle of 110 degrees and delivers 0.4 gallons per minute at a pressure of 40 PSI. Of course that both spray angle and volume are pressure-dependent. The relationship between pressure and flow can be described by the following equation,

$$\frac{Q_1}{Q_2} = \sqrt{\frac{P_1}{P_2}}$$

We can use this relationship to find nozzle flow information at a different pressure setting given that we know flow information at a particular pressure.

Let's work out an example:

- ✓ What is the flow of an 11004 when subjected to a pressure of 60 PSI?

Answer: An 11004 will deliver 0.4 gallons per minute at 40 PSI. To find out the volume delivered at 60 PSI, let's use the equation:

$$\frac{0.4}{Q_2} = \sqrt{\frac{40}{60}}$$

The volume at 60 PSI is equal to 0.49 gallons per minute.

Good calibration techniques demand that we measure flow of all nozzles and compute an average flow per minute for the entire boom. Any nozzle delivering more or less than 5% of the mean boom value should be discarded and replaced.

Let's work out an example:

- ✓ A mean boom value of 0.385 gallons per minute was calculated. The boom is equipped with 11004 nozzle tips. What are the maximum and minimum values beyond which nozzles should be replaced?

Answer: Nozzles delivering plus or minus 5% of the boom mean value should be replaced. In this case, a mean value of 0.385 gallons per minute yield values of {0.365, 0.404}. Nozzles that are delivering less than 0.365 gallons per minute or more than 0.404 gallons per minute should be discarded and replaced.



4. Operating Pressure

- The operating pressure affects the flow of liquid through the nozzles. As stated before, increasing pressure will increase nozzle flow, although this relationship is not linear. Nozzle manufacturer’s catalog brings information on the required pressure in order to achieve the desired application rate. Be sure that your pressure transducer is working properly. Have them checked and replaced if necessary at your local dealer.

Putting it all together

Finally, after checking all necessary components it is time to calibrate the sprayer. There are a few different methods to follow for sprayer calibration, but we will concentrate in the two most commonly used.

VOLUME METHOD

In the volume method, we start with the desired application rate (GPA) and measure ground speed (MPH) and effective swath width (W). We then need to find the proper volume (GPM) to be delivered by the nozzles at the desired operating pressure. We use the following equation,

$$GPM = \frac{GPA \times W \times MPH}{5940}$$

Let’s work out a few examples:

- ✓ In a field broadcast application of 10 gallons per acre (GPA), speed was measured to be equal to 9.7 miles per hour (MPH) and nozzle spacing is 40 inches (W). What is the needed nozzle flow to achieve the desired application rate?

Answer: Applying the formula, $GPM = \frac{10 \times 40 \times 9.7}{5940} = 0.653$

Therefore a nozzle tip delivering 0.653 gallons per minute is needed to achieve the desired application rate.

To adjust the nozzle properly, fill the sprayer with water and spray at a desired initial operating pressure (i.e. 40 PSI) for a specified time. Collect spray using a graduated receptacle. It is recommended to collect spray from several different nozzles to obtain a representative boom sample. Increase or decrease the system’s pressure until the volume collected is equal to the desired value.

- ✓ In a banding application, a desired rate of 15 gallons per acre (GPA) is to be applied. Band width is 18 inches (W) and speed was measured to be 7 miles per hour (MPH). What is the needed nozzle flow to achieve the desired application rate?

Answer: Applying the formula, $GPM = \frac{15 \times 18 \times 7}{5940} = 0.318$

Therefore a nozzle tip capable of delivering 0.318 gallons per minute is needed to achieve the desired application rate.



- ✓ In a direct application, 3 nozzles are used to direct spray over 36-inch bands in 72-inch sugar cane plants. The desired application rate is 10 gallons per acre (GPA). Speed used is 8.5 mile per hour (MPH). What is the needed nozzle flow to achieve the desired application rate?

Answer: This is a direct application because 3 nozzles are used to direct spray to the plants and it is also a banded application because only 36 inches are being treated of a total of 72 inches. The effective swath width is $\frac{36}{3} = 12$ inches. Using the formula,

$$GPM = \frac{10 \times 12 \times 8.5}{5940} = 0.171$$

A nozzle tip capable of delivering 0.171 gallons per minute is needed in this direct application.

AREA METHOD

In the area method we first need to find out a suitable distance to collect spray from the nozzles. This distance will vary according to nozzle spacing, band width, or effective swath width. Refer to the following table to find the distance needed.

Width (in)	Distance (ft)
12	340
14	291
16	255
18	227
20	204
22	185
24	170
26	157
28	146
30	136
32	128
34	120
36	113
38	107
40	102
44	93
48	85
54	76
58	70
60	68
66	62



Width (in)	Distance (ft)
68	60
70	58
72	57

Table 1. Effective swath width and distance needed for sprayer calibration.

- Measure the distance found in Table 1 in the field to be sprayed, or in a field with similar terrain conditions.
- With the usual tractor gear arrangements, record the time needed to cover the marked distance. Repeat this process at least three times.
- At a stationary position, start spraying water through the nozzles. Using a graduated receptacle collect the volume sprayed during the same amount of time recorded during the speed calibration. Collect volume from 3 to 5 different nozzles.
- The amount of water collected in ounces, is equal to the application rate in gallons per acre.

Let's work out an example:

- ✓ Broadcast application of 15 gallons per acre (GPA). Nozzle spacing is 40 inches. Distance needed for speed check is 102 feet (found in Table 1). Distance is marked in the field and time spent to cover 102 feet recorded. Process is repeated 3 times. Average time needed to cover 102 feet is calculated as 8.1 s. Sprayer is then turned on and volume is collected during 8.1 s with a graduated receptacle. The collection process is done 3 to 5 times using different nozzles in the boom. An average flow of 12 ounces (oz) is collected. Since desired application rate is 15 GPA, the pressure needs to be increased to increase flow. After pressure is increased, a new volume collection is made in 5 nozzles during 8.1 s. The average volume collected is 15 ounces (oz). The application rate is then set for 15 GPA.
- If your application is a directed application using more than one nozzle, collect volume from all nozzles that are directed to the same plant or band.

MIXING EXAMPLES

Often mixing the correct amount of chemicals in the tank is as difficult as finding a correct sprayer calibration. A few examples are given here to help understanding these procedures.

Example 1. An 8-row planter at a speed of 5mph is equipped with 1 nozzle per row, and 2, 200-gallon saddle tanks. The volume flow of the nozzle is 0.281 gallons per minute. The band to be treated has width of 14 inches. Row spacing is 30 inches. The chemical concentrate has 3 lbs/gallon and an application rate of 1.25 lbs/acre is need. Concentrate is sold in 2.5-gallon containers. The field to be sprayed has 50 acres. Find out what the amount of concentrate needed and the tank mixture.

We can rearrange the GPM formula to find the application rate needed (GPA).

$$GPM = \frac{GPA \times W \times MPH}{5940}$$



Becomes

$$GPA = \frac{GPM \times 5940}{W \times MPH}$$

Then,

$$GPA = \frac{0.281 \times 5940}{14 \times 5} = 23.8$$

The application rate is 23.8 gallons per acre. The field has 50 acres, but we are treating only 14 of every 30 inches. The total solution amount is $\frac{23.8 \times 50 \times 14}{30} = 555.3$ gallons. An application rate of 1.25 lbs/acre is recommended, the total product needed is $\frac{1.25 \times 50 \times 14}{30} = 29.1$ lbs. Since the chemical concentrate has 3 lbs per gallon, $\frac{29.1}{3} = 9.7$ gallons are needed. From a total of 555.3 gallons, 9.7 gallons are chemical concentrate and the remaining 545.6 gallons are just water. The ratio of water to chemical is $\frac{545.6}{9.7} = 56.2$. For every gallon of chemical concentrate, 56.2 gallons of water are needed, totaling 57.2 gallons. In a 400-gallon tank, $\frac{400}{57.2} = 7$ gallons of concentrate are needed and $400 - 7 = 393$ gallons of water.

Example 2. Eight oz/ac of an herbicide are recommended at a solution rate of 10 gallons/ac. The sprayer tank has 500-gallon capacity and the field has 175 acres.

- How much product is needed?
- How much water is needed?
- The tank mixture ratio.

We need 8 oz per acre. Total field area is 175 acres. Total product needed is $\frac{175 \times 8}{128} = 10.9$ gallons. Remember that are 128 ounces in 1 gallon. We're going to apply 10 gallons per acre in 175 acres, so the solution total is 1,750 gallons. Since 10.9 gallons are herbicide, the total amount of water is $1,750 - 10.9 = 1739.1$ gallons of water. The ratio water/herbicide is $\frac{1739.1}{10.9} = 159.5$. For every gallon of herbicide, 159.5 gallons of water are needed, totaling 160.5 gallons. For a 500 gallon tank, the ratio is $\frac{500}{160.5} = 3.1$ gallons of herbicide and 496.9 gallons of water.



SPECIFIC GRAVITY EXAMPLES

Since solutions are not pure water, attention has to be given to the specific gravity of the mix. Nozzle catalogs bring information on nozzle flow based on spraying water. If the solution has a specific gravity different from the water's, misapplication will occur. Specific gravity is the calculation of the solution's density using the following formula.

$$SG = \frac{Mass}{Volume}$$

Pure water has a specific gravity of 1. For products with other specific gravity values, a conversion factor has to be applied. To calculate a conversion factor, weigh a known volume of the solution and calculate its specific gravity. The conversion factor (CF) will be

$$CF = \sqrt{SG}$$

Table 2 brings values of several specific gravities and their corresponding conversion factors.

Solution's Weight (lbs/gal)	Specific Gravity (SG)	Conversion Factor (CF)
7	0.84	0.92
8	0.96	0.98
8.34 ^a	1.00	1.00
9	1.08	1.04
10	1.2	1.10
10.65 ^b	1.28	1.13
11	1.32	1.15
12	1.44	1.20
13	1.55	1.25
14	1.68	1.30
15	1.79	1.38

Table 2. Different solutions' weight, their specific gravity and conversion factor.
^a water, ^b 28% nitrogen.

Examples:

- A solution containing a mix of different herbicides and adjuvant weighs 7.8 lbs per gallon. Calculate its specific gravity and conversion factor. The nozzle to be used in this application is rated 11004. How much solution it will spray, in gallons per minute?

Answer:

Calculating the specific gravity for the mixture,



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$$SG = \frac{7.8lbs}{1gal} \times 0.1198 = 0.934 .$$

The conversion factor is calculated as $CF = \sqrt{0.934} = 0.966$.

The nozzle 11004 delivers 0.4 gallons per minute of pure water. To find out what is the flow of a solution with different specific gravity, the following formula is used,

$$Sol \times CF = Water .$$

With a solution which specific gravity is 0.934, it will deliver $\frac{0.4}{0.966} = 0.414$ gallons.

- Application rate of 10 gallons per acre of a solution which weighs 9 lbs/ gallon. What nozzle information to use?

Answer:

A solution with 9 lbs/gallon has specific gravity of 1.08 and conversion factor of 1.04 (see Table 2). Applying the formula, the equivalent in water is $10 \times 1.04 = 10.4$. The applicator should choose a nozzle size that will supply 10.4 GPA of water at the desired pressure.



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USEFUL CONVERSIONS

LENGTH

1 foot = 12 inches
1 yard = 3 feet
1 inch = 2.54 cm = 25.4 mm
1 meter = 3.281 ft = 39.37 in
1 mile = 1,609 m = 5,280 ft

AREA

1 acre = 43,560 ft² = 0.4047 ha = 4,840 yd²
1 m² = 10.76 ft²
1 ft² = 144 in²

VOLUME

1 pint = 2 cups = 16 fl oz
1 gallon = 4 qt = 8 pints = 128 oz = 3.785 liters
1 ft³ = 7.48 gallons
1 bushel = 1.245 ft³
1 m³ = 35.31 ft³

WEIGHT

1 oz = 0.0625 lb = 28.35 g
1 lb = 16 oz = 454 g
1 kg = 2.205 lb

SPEED

1 ft/s = 0.681 mph = 0.304 m/s
1 mph = 1.609 km/hr

PRESSURE

1 PSI (lb_f/in²) = 144 lb_f/ft² = 0.068 atm = 2.31 ft of H₂O

TEMPERATURE

Degrees Celsius (°C) = $\frac{5}{9}$ (°F – 32)